

**COLLOCATION IMPACTS ON THE VULNERABILITY OF LIFELINES DURING
EARTHQUAKES WITH APPLICATION TO THE CAJON PASS, CALIFORNIA**

TABLE OF CONTENTS

Volume 1

ITEM	PAGE
Table of Contents.....	i
List of Figure.....	ii
List of Tables.....	v
1.0 CONCLUSIONS	1
2.0 INTRODUCTION	4
2.1 Background	4
2.2 Study Approach	5
2.3 Chapter 2.0 Bibliography	6
3.0 SUMMARY	6
4.0 ANALYSIS METHOD	8
4.1 Data Acquisition	11
Lifeline and Geologic Information	11
Ground Shaking Intensity	13
Selection of the Earthquake Event	16
4.2 Calculation of Lifeline Vulnerability	16
Damage Assessment	16
Shaking Damage	18
Fault Displacement	23
Soil Movement	24
Landslide	24
Liquefaction or Lateral Spread	30
Highway and Railway Bridges	31
Times to Restore the Lifeline to its Needed Service	37
Repair Time	37
Access Time	38
Equipment and Material Time	39
4.3 Collocation Analysis	39
Impacts on Damage State	42
Impacts on Probability of Damage	42
Impacts on Time to Restore Lifeline Service	43
4.4 Interpretation of the Results	44
4.5 Chapter 4.0 Bibliography	45
5.0 APPLICATION OF THE METHOD TO CAJON PASS	47
5.1 Data Acquisition	47
5.2 Lifeline Collocation Vulnerability Analysis Results	55
Communication Lifelines	61
Electric Power Lifelines	68
Fuel Pipeline Lifelines	75
Transportation Lifelines	81
5.3 Chapter 5.0 Bibliography	91
6.0 FUTURE STUDY NEEDS	91

Appendix A Modified Mercalli Intensity (MMI) Index Scale

LIST OF FIGURES

FIGURE	PAGE
Figure 1 Flow Chart of the Analysis Method	9
Figure 2 The "Attenuation Parameter k" for Use in Calculating Earthquake Shaking Intensity	15
Figure 3 Map of the U.S. Seismic Hazard Regions	22
Figure 4 Liquefaction Induced Damage	32
Figure 5 Map Showing the General Location of the Cajon Pass Study Area	48
Figure 6 A Composite of the Lifeline Routes at Cajon Pass	50
Figure 7 Identification of Collocations At Cajon Pass	52
Figure 8 Lifeline Routes With Shaking Intensity and Potential Landslide and Liquefaction Areas	54
Figure 9 Communication Lifeline Routes.....	62
Figure 10 Fiber Optic Conduits On A Bridge On The Abandoned Portion of Cajon Blvd. Extension	63
Figure 11 Details of the Fiber Optic Conduits of Figure 10	63
Figure 12 Fiber Optic Conduits On A Concrete Culvert That Passes Under I-15	64
Figure 13 Wall Support Details for the Fiber Optic Conduits Shown in Figure 12	64
Figure 14 Surface Water Conditions Near The Toe of The I-15S Retaining Crib Wall	65
Figure 15 Fiber Optic Conduits Under a Heavy Water Pipe, Both On a Highway Bridge	65
Figure 16 Electric Power Lifeline Routes	69
Figure 17 A Landslide Scar With Power Towers in the Slide Area ..	70
Figure 18 Power Lines, Natural Gas and Petroleum Products Pipelines Intersecting Over the San Andreas Fault Rift Zone	71

Figure 19 Power Tower at a Ravine Edge in the San Andreas Fault Rift Zone	72
Figure 20 Fuel Pipeline Lifeline Routes	76
Figure 21 Typical Long Open Span on the 36-Inch Natural Gas Pipeline	75
Figure 22 Two Natural Gas Pipelines Located Next to Highway 138 .	77
Figure 23 Natural Gas Pipeline Crossing Under Railroad Beds	78
Figure 24 Transportation Lifeline Routes	83
Figure 25 I-15 Bridge Over Railroads in Cajon Wash	84
Figure 26 I-15 Bridge Over Cajon Wash	84
Figure 27 Highway 138 Bridge Over I-15	85
Figure 28 Railroad Bridges in Cajon Wash (I-15 Bridge in Background)	86
Figure 29 Railroad Bridge Over Highway 138 (Collapse Expected) ..	86
Figure 30 Santa Fe Railroad Bubble Masonry Pier Bridge	87
Figure 31 Union Pacific Railroad Bridge With Power Lines Overhead	87
Figure 32 Typical I-15 Box Bridge Over the Railroads	90
Figure 33 I-15 and Access Road Bridges Over the Southern Pacific Railroad	90

LIST OF TABLES

TABLE

PAGE

TABLE	PAGE
Table 1. CAJON PASS IMPACTS OF LIFELINE PROXIMITY: EXPERT TECHNICAL ADVISORY GROUP	6
Table 2. ATC-13 DEFINITION OF LIFELINE DAMAGE STATE	17
Table 3 SHAKING DAMAGE PROBABILITY MATRICES, ATC-13 Tables 7.10	19
Table 4 MMI ADJUSTMENTS FOR SHAKING DAMAGE EVALUATIONS TO ACCOUNT FOR LOCAL CONDITIONS	23
Table 5 LIFELINE DAMAGE STATE FOR FAULT SURFACE DISPLACEMENTS, ATC-13 Table 8.9	24
Table 6 SOIL PARAMETERS FOR CALCULATING LANDSLIDE POTENTIAL ...	26
Table 7 LANDSLIDE SLOPE FAILURE PROBABILITY MATRICES, ATC-13 Table 8.7	27
Table 8 CONVERSION OF LANDSLIDE SLOPE FAILURE STATE TO DAMAGE STATE, ATC-13 Table 8.8	29
Table 9 RELATIONSHIP BETWEEN LIQUEFACTION SEVERITY INDEX (LSI) AND DAMAGE STATE	30
Table 10 PROBABILITY OF LIQUEFACTION GROUND FAILURE, PERCENT ...	31
Table 11 RELATIONSHIP OF BRIDGE VULNERABILITY INDEX TO BRIDGE DAMAGE STATE	33
Table 12 BRIDGE VULNERABILITY INDEX FOR EARTHQUAKE SHAKING DAMAGE	35
Table 13 ESTIMATED LIFELINE REPAIR TIMES TO 100% OPERATING CAPACITY, ATC-13 Table 9.11	38
Table 14 LIFELINE ZONES OF PHYSICAL INFLUENCE	41
Table 15 MATRIX OF LIFELINE COLLOCATION AND INTERACTIONS	56